

## **APPENDIX I**

### **RESPONSE TO ENVIRON INTERNATIONAL CORPORATION REPORT ON WEEKEND-WEEKDAY DIFFERENCES IN OZONE AND OZONE PRECURSORS IN THE SOUTH COAST AIR BASIN**

#### **Do lower NO<sub>x</sub> emissions cause the higher ozone on weekends in the South Coast Air Basin?**

Outdoor levels of ozone on the weekend are generally higher than on weekdays in the South Coast Air Basin (SoCAB). This issue is documented by ENVIRON International Corporation in a study sponsored by the American Automobile Manufacturers Association. The ENVIRON investigators found that levels of nitrogen oxides (NO<sub>x</sub>) are lower on weekend mornings than during the week, which led them to conclude that NO<sub>x</sub> control is counterproductive to reducing ozone levels. The following pages summarize ARB staff's review of ENVIRON's report and documents the uncertainties and deficiencies that lead ARB staff to conclude that there is insufficient evidence in the report to support its conclusion.

#### **Lower NO<sub>x</sub> levels do not necessarily result in lower ozone levels.**

Ambient concentrations of ozone on the weekend days are generally higher than on weekdays in the South Coast Air Basin (SoCAB). More precisely stated, ambient concentrations of ozone on Saturdays are generally higher than on any other day of the week in the SoCAB. ENVIRON asserted that this coincidence of higher ambient ozone concentrations and lower nitrogen oxides (NO<sub>x</sub>) concentrations on weekend days demonstrates that lowering NO<sub>x</sub> emissions is harmful to the control of ambient ozone. This "NO<sub>x</sub> disbenefit" conclusion is an extrapolation of the well-known reaction of ozone with nitric oxide (NO) to form nitrogen dioxide (NO<sub>2</sub>) and molecular oxygen (O<sub>2</sub>). However, analysis of Friday to Saturday and Saturday to Sunday NO<sub>x</sub> and ozone concentrations suggests a different pattern than the ENVIRON analysis suggests (Blier and Winer, 1998). Ambient data from Friday to Saturday do show that lower early morning concentrations of NO<sub>x</sub> coincide with higher ozone, but from Saturday to Sunday the data show the opposite result -- lower early morning concentrations of NO<sub>x</sub> coincide with lower ozone. This more careful examination of ambient data provides no convincing evidence of "NO<sub>x</sub> disbenefit."

#### **Temporal differences between weekday and weekend emission are not considered.**

To show lower NO<sub>x</sub> emissions on weekend days, ENVIRON staff used early morning ambient concentrations of NO<sub>x</sub> (average from 6-10 a.m.) as a surrogate for total NO<sub>x</sub> emissions. For this to be entirely true, the activity pattern (timing of emissions) must be similar for all days of the week. Weekend day and weekday emission patterns may be substantially different from each other. The ENVIRON assertion that higher ozone during the weekend day are caused by lower emissions of NO<sub>x</sub> cannot be proven from the facts they have presented. Perhaps even more critically, ENVIRON staff do not present a weekend emission inventory. Without a tested and validated weekend emission inventory, discussion of the weekend NO<sub>x</sub> emissions in the SoCAB has a high degree of uncertainty.

### **Pollutant “carryover” from prior day’s emissions is not considered.**

Ozone trapped from one day’s emissions above the nighttime boundary layer can mix down and increase ozone concentrations at ground level during the next morning. Total non-methane hydrocarbons (TNMHC) and NO<sub>x</sub> likely also behave in a similar way. In this way, emissions from one day can impact similar concentrations on the next day. These processes are called “carryover” of pollutants from one day to the next. The best way to study the weekend effect is viewing it as a three-dimensional phenomenon that may be explained by differences in the amount and timing of emissions, as well as by transport of air pollutants from one day to the next. Some evidence of the importance of carryover is in the relative change in ozone from the start of the weekend to the start of the week. An initial rise in ozone values in percentage terms between Friday and Saturday is roughly offset by declining ozone values in percentage terms from Saturday to Sunday and from Sunday to Monday (Blier & Winer, 1998). ENVIRON does not present any study of the carryover effect.

### **Statistical analyses are not consistent.**

ENVIRON analysis approach is also inconsistent. They are inattentive to correlation structures when applying t-tests, for instance, to Thursday-Friday mean versus Monday-Wednesday mean as in page 17 of the ENVIRON report. This weakens the strength of the ENVIRON staff’s statistical reasoning. Time periods selected for comparison are also not consistent. For example, in the analysis of ozone trends, investigators focus on daily means (i.e. Saturday, Sunday, Monday, etc), but for analysis of precursors, they average other days together (i.e. Monday-Friday and Saturday-Sunday means for ozone precursors). Without consistent analyses, cause-and-effect relationship cannot be established.

ENVIRON staff noted that weekend-weekday differences were higher in the coastal, metropolitan, and San Gabriel valley subregions of the SoCAB and lower further east in the basin between 1986 and 1989 and that such geographic differentiation did not exist between 1994 and 1996. In an earlier ARB sponsored study, Blier and Winer (ARB 1996) analyses for 1986 to 1989 and for 1990 to 1993 had reached a similar conclusion. It is unclear why the period of 1990 to 1993 was deleted from the ENVIRON analysis. Unlike the ENVIRON approach, Tran and Larsen (ARB 1996) used detailed cluster analysis to arrive at a probabilistic and appropriate treatment of geographical variability of the weekend phenomena in the SoCAB. Their analysis identified several different geographical patterns for the weekend phenomenon not found among the ENVIRON findings. The Tran and Larsen findings are substantial in this regard because they allowed a statistical analysis to guide them in deciding geographical associations between adjacent sites rather than relying on a set of arbitrary assumptions about what areas constitute coastal, central, or inland subregions of the SoCAB. Such designations have changed as the SoCAB has grown and expanded. ENVIRON’s analytical approach attempting to show that the “NO<sub>x</sub> disbenefit” has expanded to eastern and northern areas of the SoCAB is thus flawed.

### **The “NO<sub>x</sub> disbenefit” is not consistent with trend information.**

ENVIRON staff’s “NO<sub>x</sub> disbenefit” explanation for the weekend effect is difficult to reconcile with certain other information within the ENVIRON report. Figures 3-15 through 3-18 in the

report clearly show a steady decrease in the peak ozone from 1986 to 1996. At no point in any year is the value of the peak increasing, as the “NO<sub>x</sub> disbenefit” would suggest. Figures 3-15 through 3-18 also demonstrate that the strategy adopted by the South Coast AQMD has been effective in reducing peak ozone levels. Figure 3-18 also shows that from 1992-1996 the ozone peaked on Saturdays but was lower on Sundays. This observation is consistent with Blier and Winer (1998) as we noted before. But the “NO<sub>x</sub> disbenefit” explanation would require higher ozone on Sundays since NO<sub>x</sub> is further reduced. It would seem that the findings of important sections of the ENVIRON report do not necessarily support the report’s conclusion.

**“NO<sub>x</sub> disbenefit” implies need for more, *not less*, NO<sub>x</sub> control.**

ENVIRON staff argue that the higher ozone with lower early morning NO<sub>x</sub> is entirely consistent with our understanding of the photochemical processes leading to ozone formation. They conclude that the lower NO<sub>x</sub> levels with the relatively unchanged TNMHC levels (when compared to weekdays) shift the chemical balance of ozone formation, making the NO<sub>x</sub> more efficient at producing ozone, and thus leading to the higher concentrations. However, they fail to report that this implies that the most effective way to reduce weekend ozone is to further control NO<sub>x</sub> emissions, contradicting their overall finding that NO<sub>x</sub> controls are counterproductive.

**Summary**

Under the ARB and the South Coast Air Quality Management District stewardship, analysis of long-term trends of SoCAB ambient data on hydrocarbons and on NO<sub>x</sub> has shown that a long-term decline has been underway in the emissions of these ozone precursors for the last two-three decades. These emission reductions have reduced ambient ozone significantly while the population and vehicle miles traveled have both significantly expanded in the SoCAB. The strategy of controlling both ozone precursors has proven successful beyond the original expectations of the air quality community. To change from a proven path of success would, at the very least, require a significant and fundamental assessment showing that this proven path is now the wrong way to go. Such an assessment should come with complete scientific credentials, successfully tested methods and hypotheses, conclusions reviewed by the academic community and consideration by all peers as a scholarly work.

The ENVIRON report’s findings of higher ozone concentrations on weekend days simultaneous with lower NO<sub>x</sub> emissions in the SoCAB cannot be proven from the facts they present. In fact, the ENVIRON report makes no effort at estimating weekend emissions. And, as comparison of Saturday vs. Sunday concentrations showed, lower ambient concentrations of NO<sub>x</sub> in the morning, as distinct from NO<sub>x</sub> emissions, are not always simultaneous with higher ozone concentrations. ENVIRON report’s “NO<sub>x</sub> disbenefit” theory to explain the weekend phenomenon, if followed to its natural conclusion, requires further NO<sub>x</sub> control that is contrary to what they recommend. There is insufficient evidence in the ENVIRON report to support its conclusion.

**References**

Blier, W., and A. Winer (1996). "Characterization of Ozone Episodes in the South Coast Air Basin: Effect of Air Parcel Residence Time and Weekend/Weekday Differences." Final Report, California Air Resources Board, Contract No. 93-316, June 28, 1996.

Blier, W., and A. Winer (1998). "Analysis of Weekday/Weekend Differences in Ambient Air Quality and Meteorology in the South Coast Air Basin." Draft Final Report, California Air Resources Board, Contract No. 95-334, February 18, 1998.

Tran, H., L.C. Larsen, and J. Austin (1996). "Analysis of the Weekday-Weekend Behavior of Ambient Concentrations of Ozone and Its Precursors." Draft Manuscript, California Air Resources Board, to be submitted to AWMA.